User Guide for

FEB-L025

Evaluation Board

Universal Line Voltage LED Ballast

Featured Fairchild Product:

FL7732

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

Fairchild Semiconductor.com

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This user guide supports the evaluation kit for the FL7732. It should be used in conjunction with the FL7732 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document describes the proposed solution for universal line voltage LED ballast using the FL7732 Primary-Side Regulator (PSR) single-stage controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 350mA at $24V_{MAX}$. This document contains general description of FL7732, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. General Description of FL7732

The FL7732 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Primary-side regulation and single-stage topology reduce external components, such as input bulk capacitor and feedback circuitry, and minimize cost. To improve power factor and Total Harmonic Distortion (THD), constant on-time control is utilized with an internal error amplifier and a low bandwidth compensator. Precise constant-current control regulates accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee DCM operation with high efficiency and simple design. FL7732 provides open-LED, short-LED, and over-temperature protections.

1.2. Features

- Cost-Effective Solution: No Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction
- Accurate Constant-Current (CC) Control, Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control Improves Efficiency and Simplifies Design
- Open-LED Protection
- Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20μA
- Low Operating Current: 5mA
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18V
- SOP-8

1.3. Internal Block Diagram

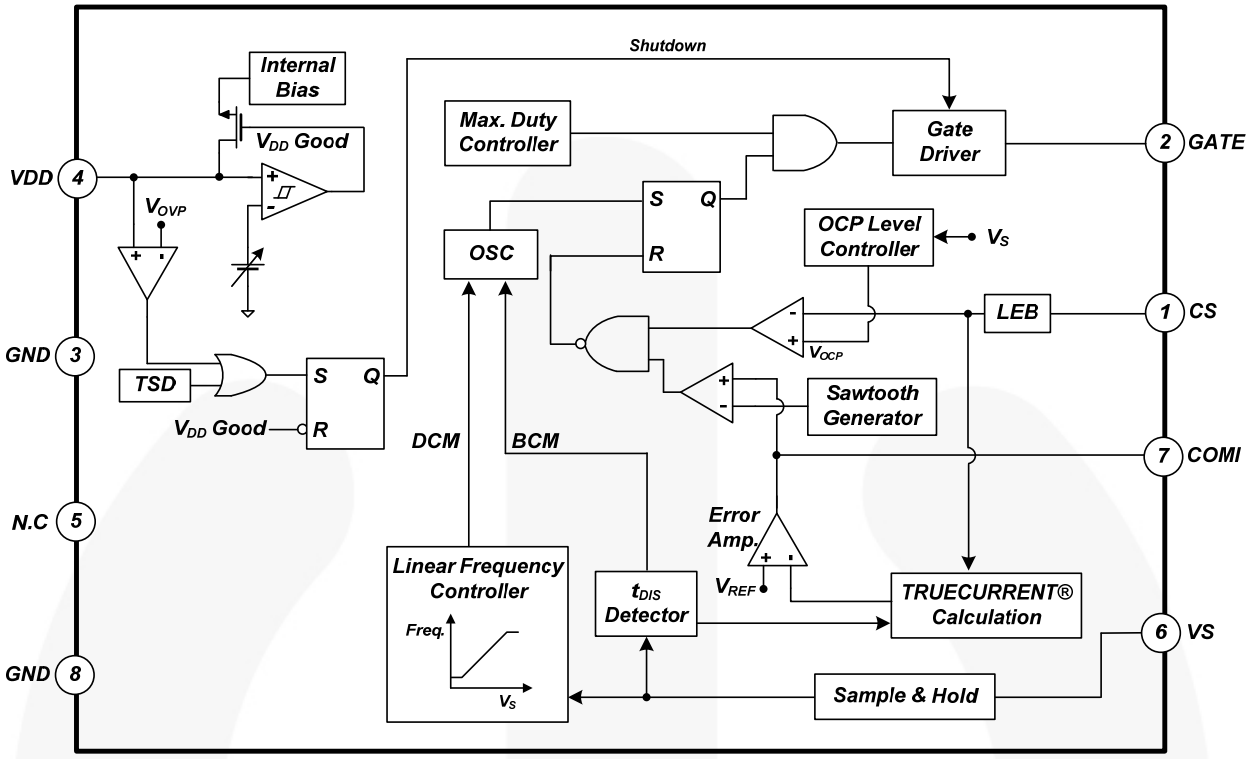


Figure 1. Block Diagram of FL7732

2. Specifications for Evaluation Board

Table 1. Specifications for LED Lighting Lamp

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90V	Minimum Input Voltage
		$V_{IN.MAX}$	265V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110V/220V	Nominal Input Voltage
	Frequency	f_{IN}	60Hz/50Hz	Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	12V	Minimum Output Voltage
		$V_{OUT.MAX}$	28V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	24V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	350mA	Nominal Output Current
		CC Deviation	< ±3.17%	Line Input Voltage Change: 90~265V_{AC}
			< ±1.93%	Output Voltage Change: 12~24V
Efficiency		Eff_{90VAC}	87.51%	Efficiency at 90V_{AC} Line Input Voltage
		Eff_{120VAC}	88.76%	Efficiency at 120V_{AC} Line Input Voltage
		Eff_{140VAC}	89.39%	Efficiency at 140V_{AC} Line Input Voltage
		Eff_{180VAC}	89.59%	Efficiency at 180V_{AC} Line Input Voltage
		Eff_{220VAC}	89.20%	Efficiency at 220V_{AC} Line Input Voltage
		Eff_{265VAC}	88.40%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD		PF/THD_{90VAC}	0.998/10.04%	PF/THD at 90V_{AC} Line Input Voltage
		PF/THD_{120VAC}	0.995/10.04%	PF/THD at 120V_{AC} Line Input Voltage
		PF/THD_{140VAC}	0.991/11.83%	PF/THD at 140V_{AC} Line Input Voltage
		PF/THD_{180VAC}	0.982/15.29%	PF/THD at 180V_{AC} Line Input Voltage
		PF/THD_{220VAC}	0.964/18.19%	PF/THD at 220V_{AC} Line Input Voltage
		PF/THD_{265VAC}	0.935/22.05%	PF/THD at 265V_{AC} Line Input Voltage
Temperature	**FL7732**	T_{FL7732}	50.8ºC	Open-Frame Condition (T_A = 25ºC) FL7732 Temperature
	Primary MOSFET	T_{MOSFET}	57.3ºC	Primary MOSFET Temperature
	Secondary Diode	T_{DIODE}	56.2ºC	Secondary Diode Temperature
	Transformer	$T_{TRANSFORMER}$	52.3ºC	Transformer Temperature

All data of the evaluation board was measured with the board enclosed in a case and an external temperature around 25°C.

2.1. Evaluation Board

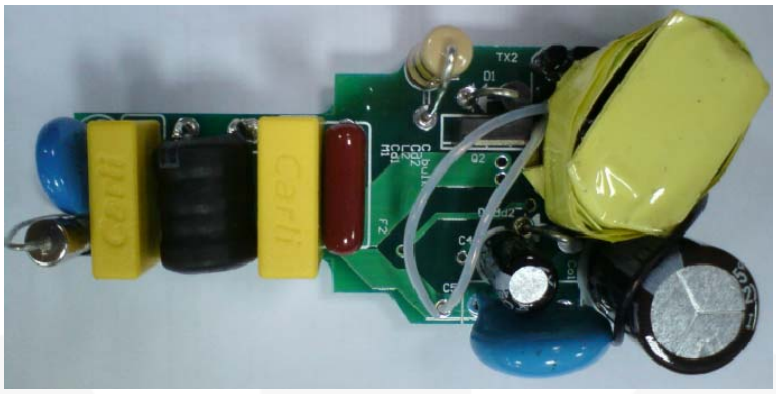


Figure 2. Top View (Dimensions: 58.0mm (L) x 26.5mm (W) x 18.0mm (H)

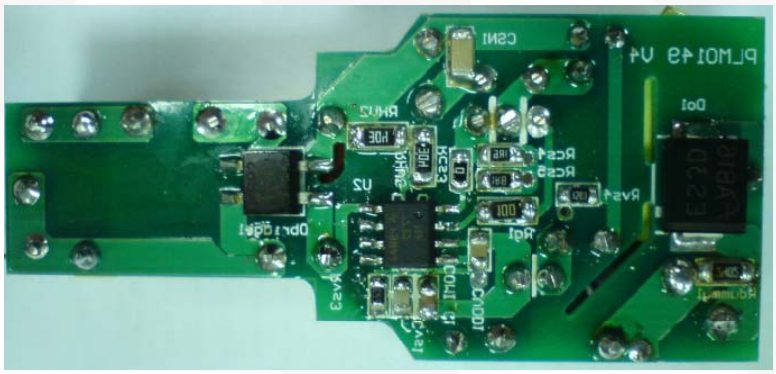


Figure 3. Bottom View (Dimensions:58.0mm (L) x 26.5mm (W) x 18.0mm (H)

2.2. Printed Circuit Board

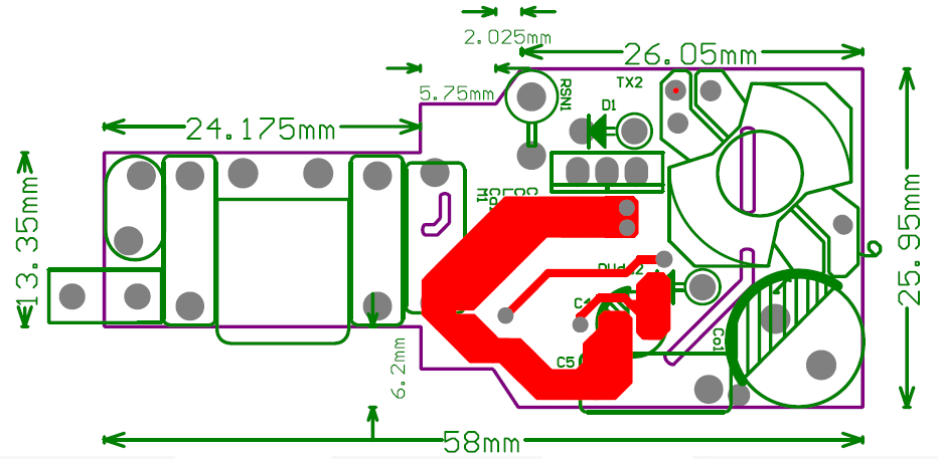


Figure 4. Top Pattern

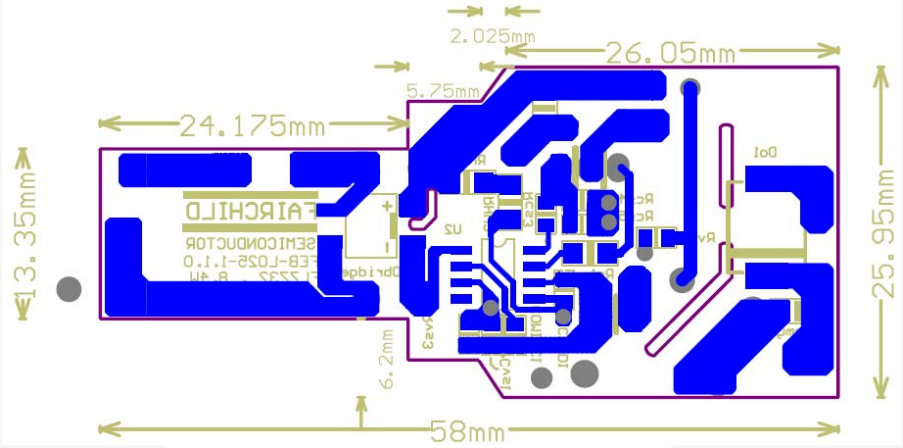


Figure 5. Bottom Pattern

2.3. Schematic of the Evaluation Board

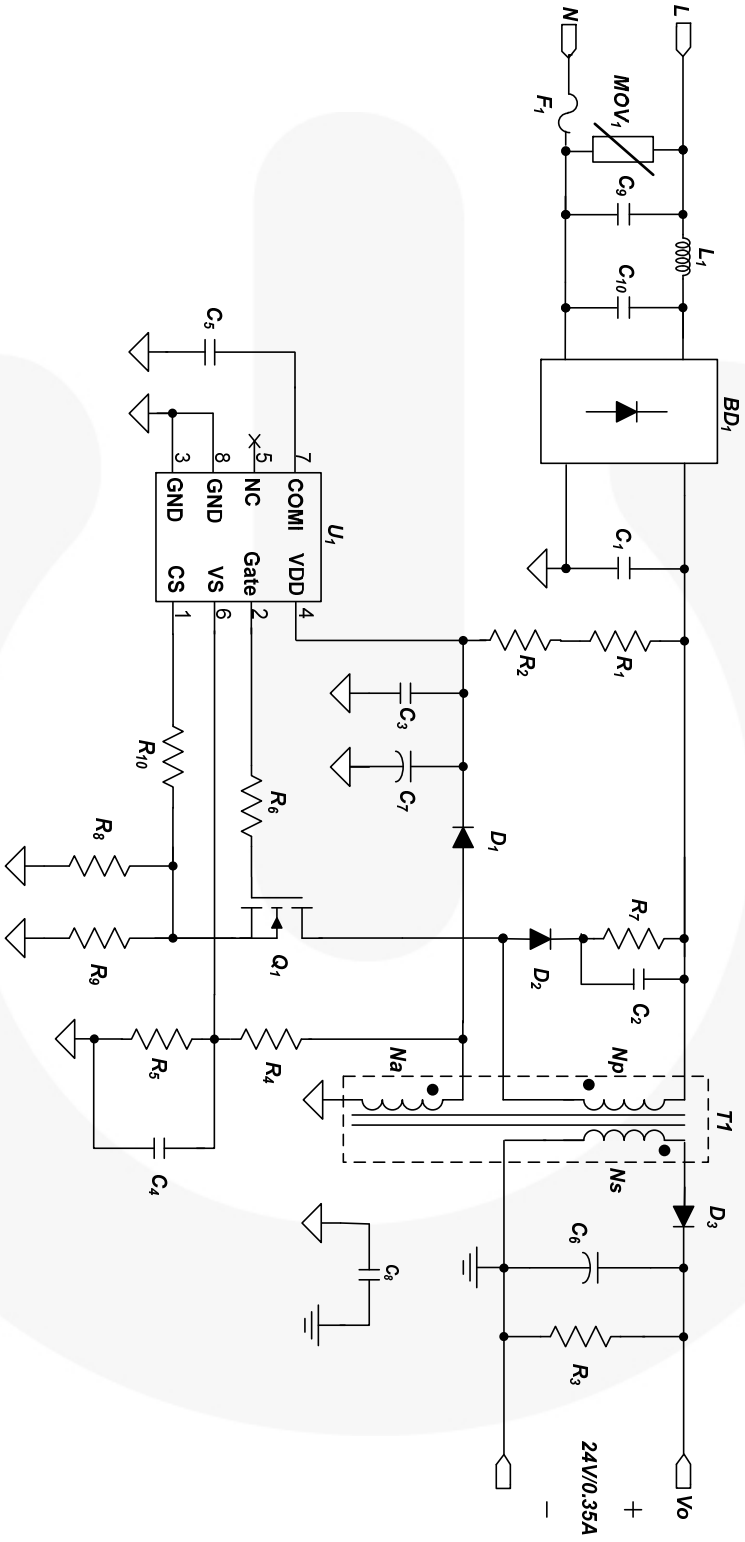


Figure 6. Schematic

2.4. Bill of Materials

Item No.	Part Reference	Part No.	Qty.	Description	Manufacturer
1	BD1	MB6S	1	0.5A/600V Bridge Diode	Fairchild Semiconductor
2	Q1	FQU5N60CTU	1	2.8A/600V Main Switch	Fairchild Semiconductor
3	U1	FL7732_F116	1	Main Controller	Fairchild Semiconductor
4	F1	SS-5-1A	1	250V/1A Fuse	Bussmann
5	M1	SVC 471 D-07A	1	Metal Oxide Varistor	Samwha
6	L1	R08123KT00	2	12mH Filter Inductor, 8Φ	Bosung
7	D1, D2	1N4007	2	1A/1000V Diode	Fairchild
8	D3	ES3D	1	3A/200V Fast Rectifier	Fairchild
9	C1	ECW-F2W104JAQ	1	104/450V Film Capacitor	Panasonic - ECG
10	C2	C1206C103KCRACTU	1	103/500V SMD Capacitor 3216	Kemet
11	C3	C0805C103K5RACTU	1	103/50V SMD Capacitor 2012	Kemet
12	C4	C0805C220J5GACTU	1	220/50V SMD Capacitor 2012	Kemet
13	C5	C0805C105Z3VACTU	1	105/25V SMD Capacitor 2012	Kemet
14	C6	KMG 470µF/35V	1	470µF/35V Electrolytic Capacitor	Samyoung
15	C7	KMG 10µF/50V	1	10µF/50V Electrolytic Capacitor	Samyoung
16	C8	SCFz2E472M10BW	1	472/250V Y-Capacitor	Samwha
17	C9	MPX AC275V 223K	1	223/AC275V X-Capacitor	Carli
18	C10	MPX AC275V 333K	1	333/AC275V X-Capacitor	Carli
19	R1, R2	RC1206JR-07300KL	2	300KΩ SMD Resistor 3216	Yageo
20	R3	RC1206JR-0724KL	1	24KΩ SMD Resistor 3216	Yageo
21	R4	RC0805FR-07150KL	1	150KΩ SMD Resistor 2012	Yageo
22	R5	RC0805JR-0722KL	1	22KΩ SMD Resistor 2012	Yageo
23	R6	RC1206JR-0710RL	1	10Ω SMD Resistor 3216	Yageo
24	R7	RSMF1JT200K	1	200KΩ/1W Metal Oxide Film Resistor	Stackpole Elec.
25	R8	RC0805JR-071R6L	1	1.6Ω SMD Resistor 2012	Yageo
26	R9	RC0805JR-071R8L	1	1.8Ω SMD Resistor 2012	Yageo
27	R10	RC0805JR-070RL	1	0Ω SMD Resistor 2012	Yageo
28	T1	RM Core	1	1mH RM6 Transformer	TDK

2.5. Transformer Design

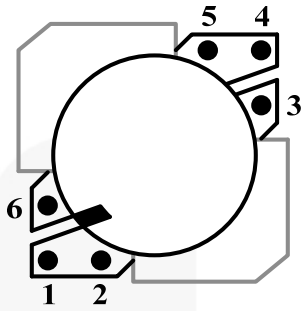


Figure 7. Transformer Bobbin Structure

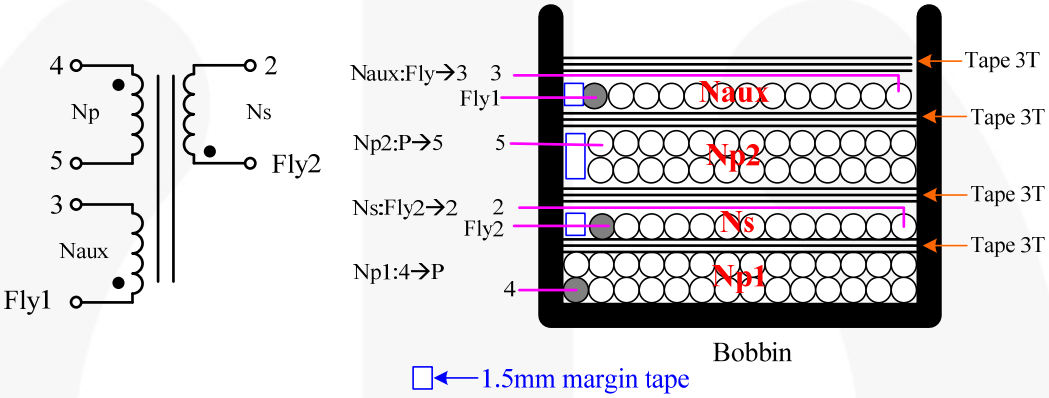


Figure 8. Pin Configuration and Transformer Winding Structure

Note:
1. Fly 1 connects to the primary side ground and Fly 2 connects to the secondary-side ground directly.

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	4 → P	0.2φ	36 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
3	N_S	Fly2 → 2	0.32φ	24 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
5	N_{P2}	P → 5	0.2φ	36 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
7	NA	Fly1 → 3	0.12φ	18 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	4 – 5	1mH ±10%	50kHz, 1V
Leakage	4 – 5	13μH	50kHz, 1V Short All Output Pins

3. Performance of Evaluation Board

Table 4. Test Condition & Equipments

Ambient Temperature	T_A = 25°C
Test Equipment	AC Power Source: ES2000S by PSTATIONES Power Analyzer: PZ4000 by YOKOGAWA Multi Meter: 2002 by KEITHLEY : 8842A by LIKE Oscilloscope: WaveRunner 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Fluke Ti20 LED: EHP-AX08EL/GT01H-P01(1W) by Everlight

3.1. Startup

Startup time is 926ms (V_{IN} = 90V_{AC}) ~ 315ms (V_{IN} = 265V_{AC}). The results were measured by using 8-LED load. Startup Time at 8-LED (24V/350mA); C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

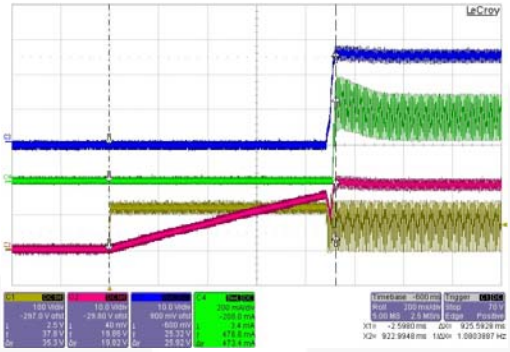


Figure 9. V_{IN} = 90V_{AC} / 60Hz

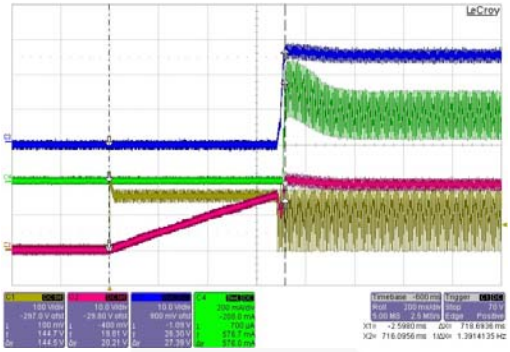


Figure 10. V_{IN} = 115V_{AC} / 60Hz

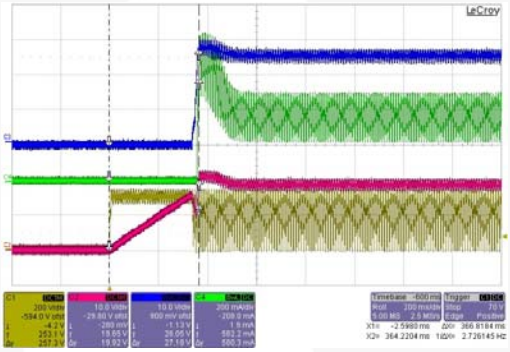


Figure 11. V_{IN} = 230V_{AC} / 50Hz

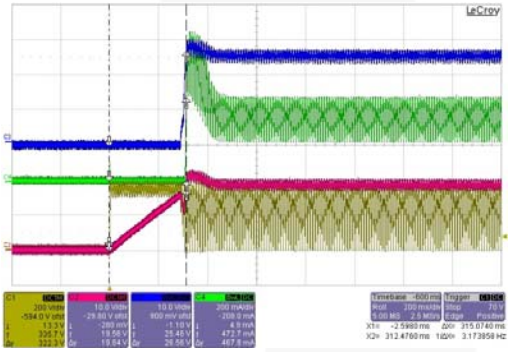


Figure 12. V_{IN} = 265V_{AC} / 50Hz

3.2. Operation Waveforms

Output current ripple is under 282mAp-p with a rated output current of 700mA. The results were measured by using actual 8-LED load. Operation Waveforms at 8-LED (24V/350mA); C1 [V_{CS}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

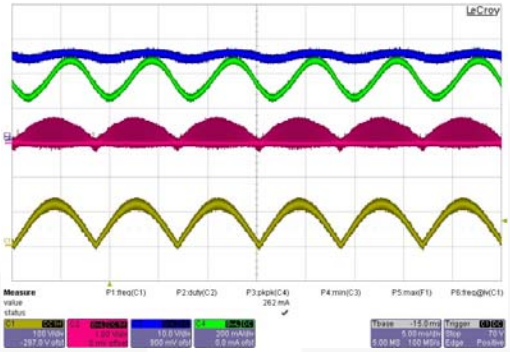


Figure 13. V_{IN} = 90V_{AC} / 60Hz

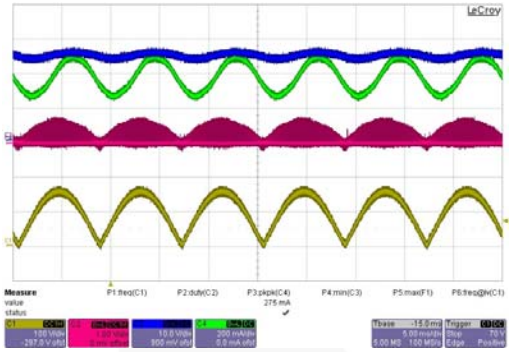


Figure 14. V_{IN} = 115V_{AC} / 60Hz

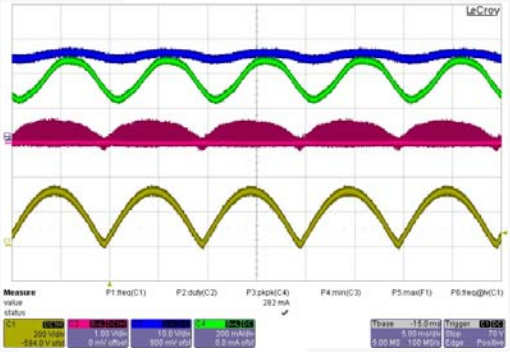


Figure 15. V_{IN} = 230V_{AC} / 50Hz

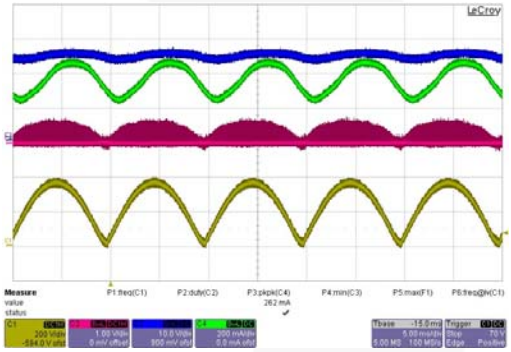


Figure 16. V_{IN} = 265V_{AC} / 50Hz

3.3. Constant-Current Regulation

Constant-current deviation in the wide output voltage range from 12V to 24V is less than ±1.93% at each line input voltage. Line regulation at the rated 6-LED is less than ±3.17%. The results were measured by using LED load.

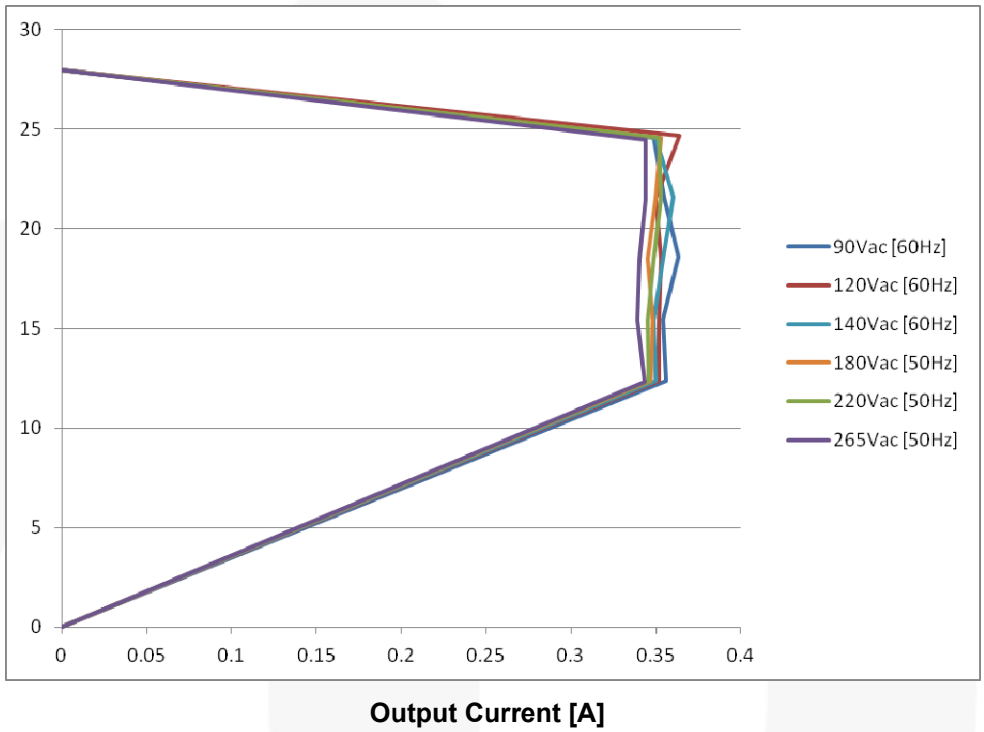


Figure 17. Constant Current Regulation, Measured by LED Load

Table 5. Constant Current Regulation by Output Voltage Change (12~24V)

Input Voltage	Min. Current [A]	Max. Current [A]	Tolerance
90V_{AC} / 60Hz	0.349	0.363	±1.93%
120V_{AC} / 60Hz	0.350	0.364	±1.92%
140V_{AC} / 60Hz	0.349	0.360	±1.53%
180V_{AC} / 50Hz	0.345	0.353	±1.13%
220V_{AC} / 50Hz	0.345	0.353	±1.13%
265V_{AC} / 50Hz	0.339	0.344	±0.73%

Table 6. Constant Current Regulation by Line Voltage Change (90~265V_{AC})

Output Voltage	90V_{AC} [60Hz]	120V_{AC} [60Hz]	140V_{AC} [60Hz]	180V_{AC} [50Hz]	220V_{AC} [50Hz]	265V_{AC} [50Hz]	Tolerance
24.5V	0.349A	0.364A	0.350A	0.353A	0.352A	0.344A	±2.75%
21.5V	0.355A	0.350A	0.360A	0.350A	0.353A	0.344A	±2.22%
18.5V	0.363A	0.353A	0.354A	0.345A	0.349A	0.340A	±3.17%

3.4. Open / Short-LED Protections

In short-LED condition, OCP level is reduced from 0.7V to 0.2V because FL7732 lowers OCP level when V_S voltage is less than 0.4V during output diode conduction time. The results were measured by using actual LED load. Short-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

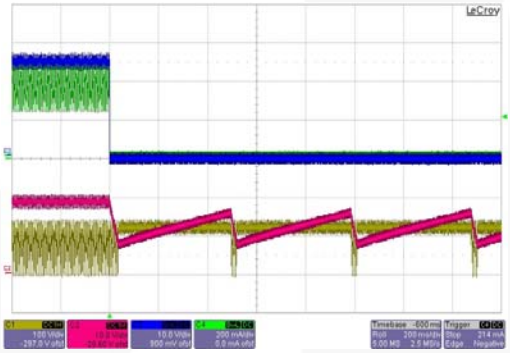


Figure 18. V_{IN} = 90V_{AC} / 60Hz

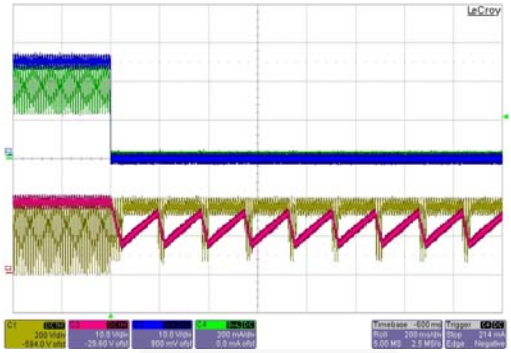


Figure 19. V_{IN} = 265V_{AC} / 50Hz

In open-LED condition, output voltage is limited around 30V by OVP in V_{DD}. Output over-voltage protection level can be controlled by the turns ratio of auxiliary and secondary windings. Open-LED Condition; C1 [V_{DD}], C2 [V_{IN}], C3 [V_{OUT}], C4 [I_{OUT}].

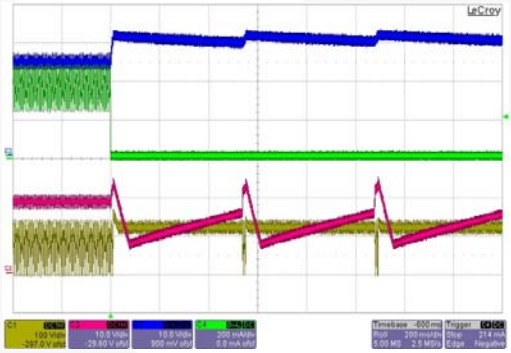


Figure 20. V_{IN} = 90V_{AC} / 60Hz

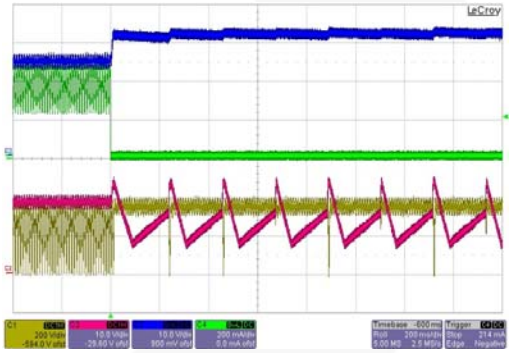
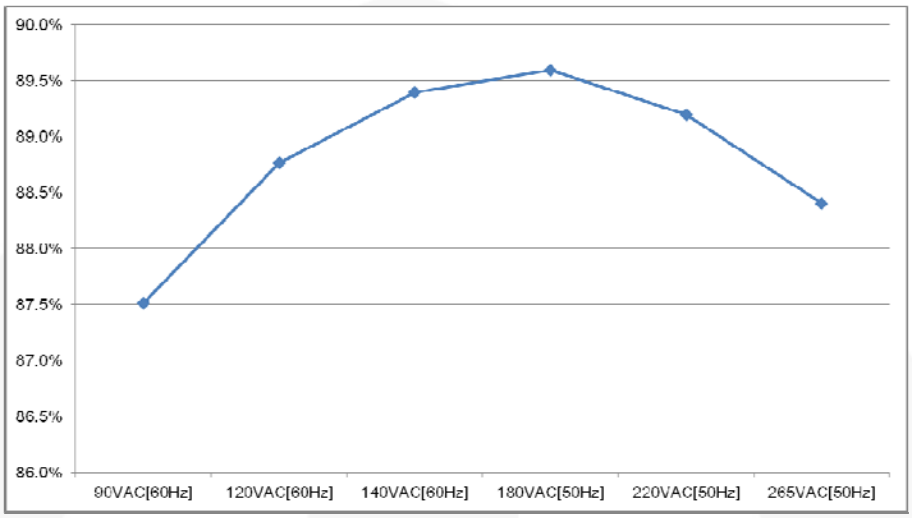


Figure 21. V_{IN} = 265V_{AC} / 50Hz

3.5. System Efficiency

The system efficiency is 87.51 ~ 89.59% in 90 ~ 265V_{AC} input voltage range. The results were measured at 30 minutes after startup by using LED load.

Efficiency



Input Voltage

Figure 22. System Efficiency

Table 7. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90V_{AC} [60Hz]	9.935	0.354	24.56	8.694	87.51%
120V_{AC} [60Hz]	10.196	0.367	24.66	9.050	88.76%
140V_{AC} [60Hz]	9.663	0.352	24.54	8.638	89.39%
180V_{AC} [50Hz]	9.677	0.353	24.56	8.670	89.59%
220V_{AC} [50Hz]	9.708	0.353	24.53	8.659	89.20%
265V_{AC} [50Hz]	9.550	0.345	24.47	8.442	88.40%

3.6. THD

FL7732 shows excellent THD performance. THD is less than 25% of the specification. Power Factor is very high; with enough margin from the 0.9 specification. The results were measured at 30 minutes after startup.

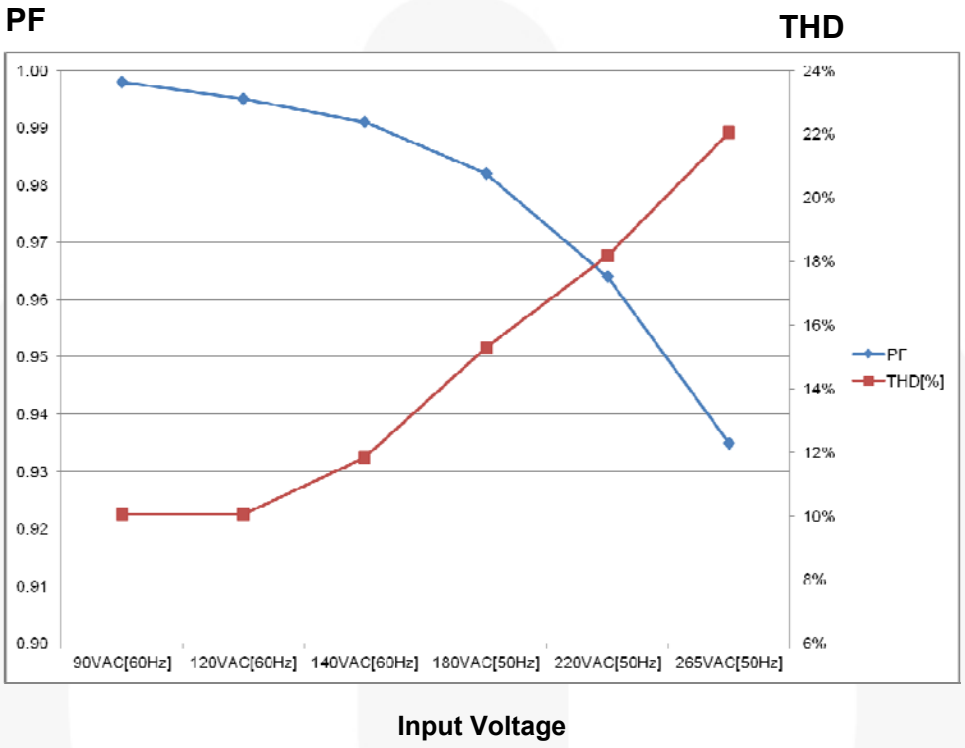


Figure 23. Power Factor and Total Harmonic Discharge

Table 8. Power Factor and THD

Input Voltage	PF	THD
$90V_{AC}$ [60Hz]	0.998	10.04%
$120V_{AC}$ [60Hz]	0.995	10.04%
$140V_{AC}$ [60Hz]	0.991	11.83%
$180V_{AC}$ [50Hz]	0.982	15.29%
$220V_{AC}$ [50Hz]	0.964	18.19%
$265V_{AC}$ [50Hz]	0.935	22.05%

3.7. Operating Temperature

The temperature of the all components on this board is less than 60°C. The results were measured 60 minutes after startup.

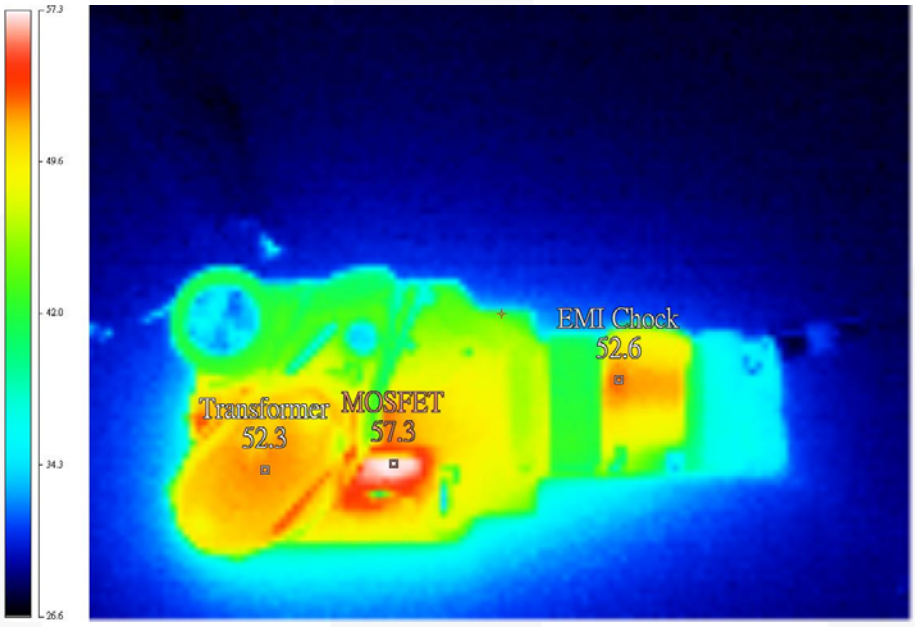


Figure 24. Board Temperature - Top View, V_{IN} [90V_{AC}] I_{OUT} [350mA]

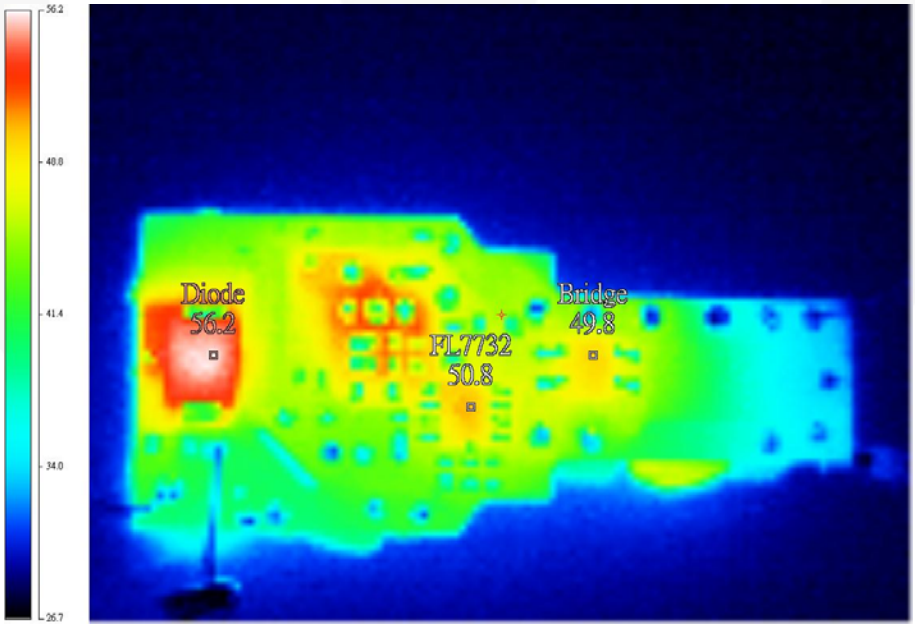


Figure 25. Board Temperature - Bottom View, V_{IN} [90V_{AC}] I_{OUT} [350mA]

3.8. EMI

All measurements were conducted in observance of EN55022 criteria. The results were measured 30 minutes after startup.

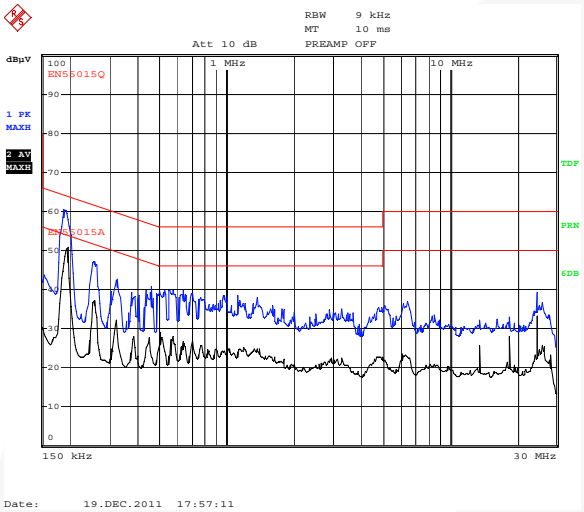


Figure 26. LIVE - V_{IN} = 115V_{AC},V_{OUT} [24V], I_{OUT} [350mA]

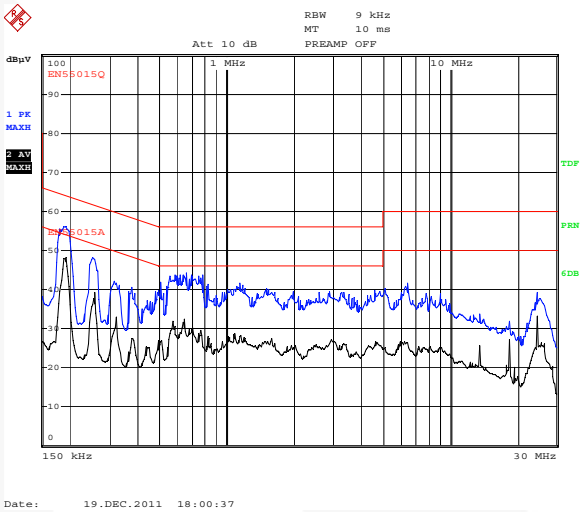


Figure 27. LIVE - V_{IN} = 230V_{AC},V_{OUT} [24V], I_{OUT} [350mA]

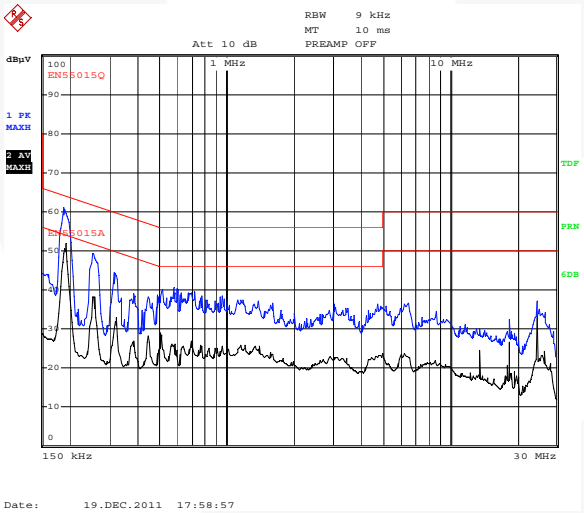


Figure 28. LIVE - V_{IN} = 115V_{AC}, V_{OUT} [24V], I_{OUT} [350mA]

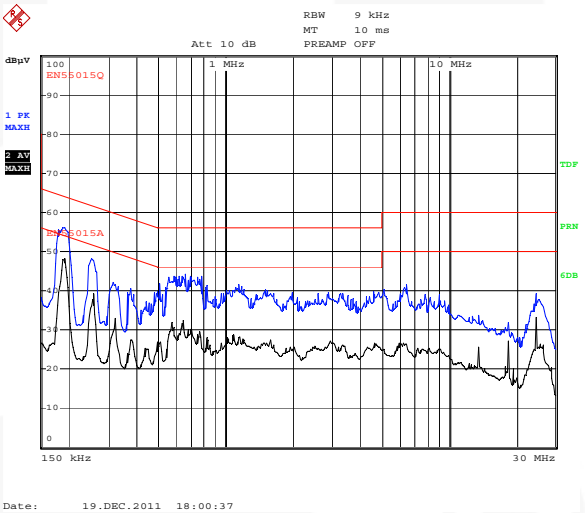


Figure 29. LIVE - V_{IN} = 230V_{AC}, V_{OUT} [24V], I_{OUT} [350mA]

4. Revision History

Rev.	Date	Description
1.0.0	April 2012	Initial Release
1.1.0	June 2012	Manufacturer & Part number are added in BOM FL7732 is changed to FL7732MY_F116 (no frequency hopping) PF/THD at 50Hz is added EMI test result is updated

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